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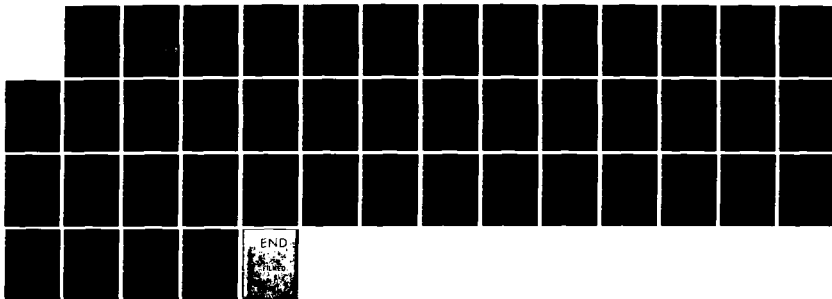
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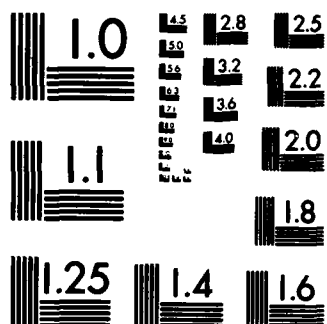
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LONGITUDINAL HEALTH RESEARCH IN THE U.S. NAVY

E. K. E. GUNDERSON

R. E. MITCHELL

R. J. BIRSNER

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P. O. BOX 85122
SAN DIEGO, CALIFORNIA 92138

NAVAL MEDICAL RESEARCH AND DEVELOPMENT COMMAND
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LONGITUDINAL HEALTH RESEARCH
IN THE U. S. NAVY¹

E. K. Eric Gunderson, Ph.D.
Head, Environmental and Social Medicine Division
Naval Health Research Center
San Diego, CA 93138

Robert E. Mitchell, M.D.
Captain, Medical Corps, United States Navy
Commanding Officer, Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, FL 32508

and

Robert J. Biersner, Ph.D.
Commander, Medical Service Corps, United States Navy
Program Manager for Human Performance
Naval Medical Research and Development Command
National Naval Medical Center
Bethesda, MD 20014

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INTRODUCTION

Longitudinal health research has many uses in military medicine. Because disease and injury reduce military performance or the readiness to perform, military commanders must be concerned about health risks to members and casualties that could impair unit effectiveness. The primary mission of the Navy Medical Department is to keep as many active duty personnel physically and mentally fit for duty as possible. Longitudinal research methods provide the means to estimate the distribution and relative risks of disease and injury in the military population so that appropriate medical support can be provided in various settings and to discover the determinants or causes so that prevention and control can be implemented. Thus, longitudinal health research is an essential component of any large-scale medical program to define health care needs and to allocate scarce resources in an optimal fashion.

The Navy has originated and conducted several longitudinal research programs during the last four decades, beginning with the Thousand Aviator Program in 1940. Two other programs, the Active Duty Enlisted Personnel Program and the Submariner/Diver Program, were later innovations. These programs involve different populations, designs and methodologies, and each was initiated to provide data about distinctive health problems. With diminishing resources and closer scrutiny by program managers over the years, the findings obtained from these programs have become more discrete and refined, with less applicability to conditions and groups that are found commonly in the general American population. (The three programs are, however, directed toward answering particular questions about the

health effects that may result from having been exposed to specific military situations.) Therefore, the earliest research, the Thousand Aviator Program, was established to determine the etiology of cardiovascular disease among naval aviators, a disease that occurs frequently among American civilians, especially among a civilian group that has much in common with naval aviators (i.e., commercial airline pilots). The most recent program, the Submariner/Diver Program, involves an analysis of the health effects that may be associated with environmental conditions (e.g., low level radiation, high carbon dioxide levels, absence of sunlight, fresh fruits and vegetables, hyperbaric pressure and exposure to high levels of trace metals) that will probably never be experienced by any American civilian group. In addition, the characteristics of the samples used in these programs restrict broad application to the civilian sector. The samples are weighted in favor of males who have above average intelligence. (Some correction for these biases is possible, however, in the Active Duty Enlisted Program described below.)

The three programs differ in the techniques used for acquiring and analyzing data. The Thousand Aviator Program adheres to a traditional methodology, representing a prospective analysis of primary (medical examination) data collected directly from project volunteers. The Active Duty Enlisted Personnel Program and the Submariner/Diver Program collate secondary data (personnel and hospitalization records, environmental measures, deployment schedules, and so forth) that are usually obtained indirectly (through archival sources such as computer or microfiche records). The Active Duty Enlisted Personnel Program, however, has the capability of being either prospective or retrospective, while the Submariner/Diver

Program is retrospective only.

The Navy Inpatient Medical Data System. Beginning with data for 1965, the Naval Health Research Center, San Diego, has constructed a computer file of inpatient medical data for active duty Navy personnel. This file contains hospitalization records, medical board actions (to determine fitness for duty and/or compensation for disability), and deaths. Each hospitalization record contains demographic and identifying information, admitting facility, dates of admission and discharge, primary and secondary diagnoses, whether or not the condition existed prior to enlistment, occupational specialty and pay grade, marital status, and medical disposition. The file is updated periodically as copies of new records are received from the Naval Medical Data Services Center, Bethesda, Maryland. A unique feature of this file is that the various record systems are compiled into individual medical histories that represent morbidity and mortality over entire naval careers and during retirement. In addition to the medical history file, a parallel service history file has been constructed for enlisted personnel. This file contains basic personnel data such as age, sex, race, marital status, education, and aptitude scores, and a chronological history of important changes in personnel status, such as promotions, demotions, unauthorized absences, desertions, discharges, and reenlistments. With this system, disease and disability histories for individuals or groups can be documented continuously and collated with military service histories.

Archival medical data used in the Active Duty Enlisted Personnel Program and Submariner/Diver Programs are a unique and important source of health information. Inpatient data are especially useful because of (a) the completeness, uniformity, and generally high accuracy of the diagnostic

data, (b) linkage to personnel records, and (c) ease of following service members throughout entire careers (20 to 30 years) and the retirement period. The limitations of such data for general epidemiologic purposes are (a) restrictions as to age and sex, and (b) sample biases resulting from induction screening standards, early discharge for diseases and injuries that interfere with military performance, and early attrition of non-career personnel. Record linkage of archival medical data to retired or active duty personnel (service history) records is made possible by routine assignment of a unique number, the Social Security Number, to the pertinent records.

The reliability of the medical data system can be verified by matching and cross-checking medical files against the personnel data files. Records that match on Social Security Number also must agree with respect to demographic and military service information. Errors found in this matching process can often be corrected on the basis of the internal consistency of information.

The integration of medical and personnel files has made possible comparative analyses of incidence, days lost, disposition, recurrence of illness or injury, disability, and death for various disease and accident categories. Risks of morbidity and mortality can be determined for any Navy occupation, work environment, or segment of the Navy population. For example, the file permits comprehensive and long-term analyses of disease and injury rates by age, sex, race, occupational specialty, job experience, pay grade, aptitude level, education, and duty assignment/geographic location. The relationship of dynamic etiological factors such as change in occupational specialty, promotions, demotions, disciplinary problems,

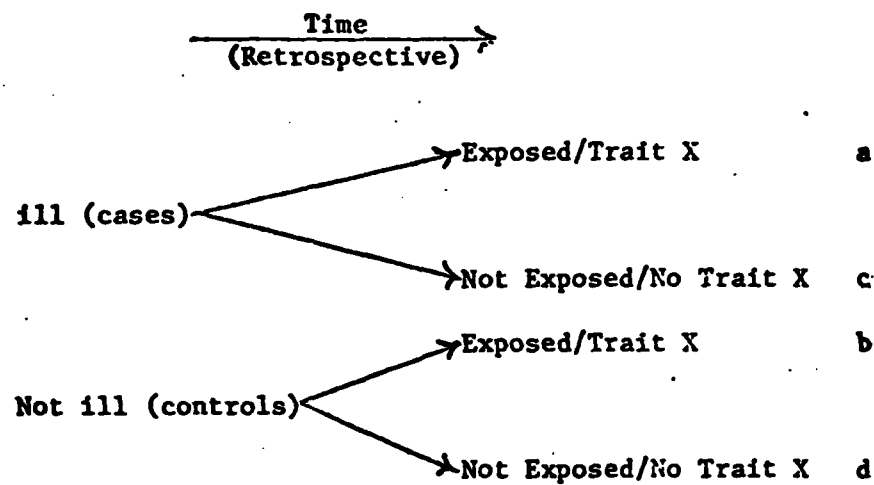
marriage and children, isolated or unusual duty assignments, training failure, and so forth with health and morbidity can be evaluated by means of cohort analyses conducted over a decade or more of naval service. While this system is unique to the Naval Health Research Center, the data are available for use by, or integration with, other longitudinal health systems (e.g., submarine personnel--see below).

General Methods and Procedures. In general, epidemiologic methods are designed to test causal relationships. Strategies of epidemiologic research involve relationships among personnel (host), environments, agents and exposure period, including the combined effects of these factors on disease and injury rates. Because epidemiology is not an experimental science (e.g., random a priori assignment of individuals to exposure situations or treatments is rarely possible), epidemiologic relationships are almost never tested directly by contrived or controlled experiments; rather, actual situations must be sought that mimic experiments as closely as possible.

Insert Figure 1 about here

Before presenting examples of Navy longitudinal health research, attention is directed to Figure 1 which illustrates the most commonly or widely used epidemiologic methods, the case-control method and the longitudinal cohort method. In the case-control method, a series of patients may be selected who manifest some disease or condition of interest (e.g., cases), and then a comparison group is selected which does not manifest the disease or condition (e.g., controls). A retrospective determination using interview, questionnaire, or archival records is then made of the number of patients who were exposed or not exposed to some harmful agent, who possessed or did not possess some trait or effect, and the number of controls

Case-Control Method



Cohort Method

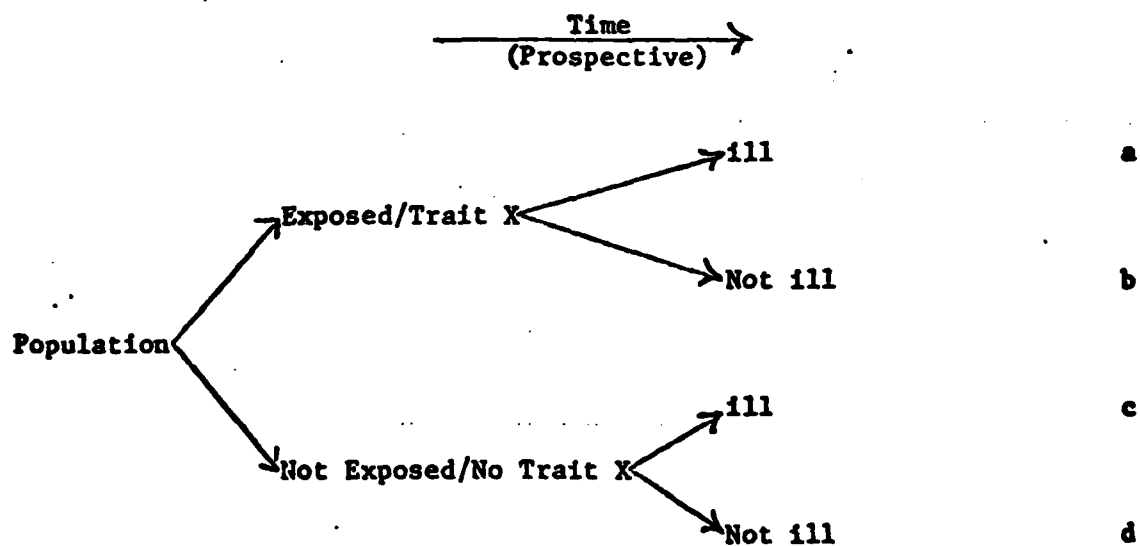


Figure 1. Two epidemiologic methods for measuring the risk of disease.

who were similarly exposed or possessed the trait. The relative risk of disease is calculated by the method shown in Table 1 (e.g., the ratio of the proportion becoming ill in the exposed group to the proportion becoming ill in the non-exposed group, or $a/a+b \div c/c+d$). If, as is usually the case, the rate of disease is low in the population, (that is, a and c are small), then the formula for relative risk reduces to the product of $a \times d$ divided by $c \times b$.

Insert Table 1 about here

The cohort method, illustrated in the lower part of Figure 1, involves selecting an unexposed population, determining who becomes exposed and who does not, and following the groups to determine the frequency with which the two groups become ill. Note that with the cohort method, the proportions $a/a+b$ and $c/c+d$ provide direct estimates of the rates of disease in the two groups. This is not the case with the case-control method: $a/a+b$ and $c/c+d$ are meaningless figures, and rates of disease for the populations cannot be estimated directly from these two groups.

The case-control method, because of simplicity and reduced costs, has been the most widely used technique in epidemiology since the 1950s. However, fundamental difficulties exist with this method. The technique is notoriously vulnerable to bias in selecting cases and controls, and results should be replicated using more exact methods. The case-control technique usually depends on patient memory of past events or on existing records for information about exposures or patient characteristics. Either of these sources may be incomplete or inaccurate. The case-control method, therefore, is generally avoided in Navy epidemiologic analyses except for preliminary, exploratory efforts.

Table 1

Computation of Relative Risk

<u>Exposure/Trait X</u>	<u>Illness</u>		<u>Total</u>
	<u>Yes</u>	<u>No</u>	
Yes	a	b	a+b
No	c	d	c+d
Total	a+c	b+d	

Incidence of disease among those exposed or with Trait X = $\frac{a}{a+b}$

Incidence of disease among those not exposed or without Trait X = $\frac{c}{c+d}$

Relative risk = $\frac{\frac{a}{a+b}}{\frac{c}{c+d}}$, or, when a and c are small, $\frac{ad}{cb}$

Following are some examples of epidemiologic analyses using the Navy Inpatient Medical Data System. Two methods, a longitudinal cohort method and a cross-sectional or non-cohort method, will be discussed. The non-cohort method simply involves computing hospitalization rates for specific subgroups over a finite period using average population strengths provided by official Navy personnel statistics as estimates of the populations at risk. Such estimates are not exact because of fluctuations in these personnel strengths. With the non-cohort method, the denominator (e.g., population at risk) is the cross-sectional estimate of the average population during a specific interval, and the numerator (e.g., number of cases) is the number of new admissions to inpatient facilities for the given condition during the specified interval. With the cohort method, an exact measure of the population at risk (e.g., the cohort) is possible. Using the entire Navy population (enlisted, submariner, or diver), fairly accurate estimates of incidence of disease by the non-cohort method can be obtained because these populations are extremely large. Using this method, major factors that are related to disease rates can be identified. More precise cohort analyses can then be conducted as needed to determine causality. The Active Duty Enlisted Personnel Program uses both the non-cohort and cohort methods, with emphasis on cohort analysis. The Submariner/Diver Program will use the non-cohort method initially because this program is of recent origin and detailed personnel descriptors remain to be developed.

Insert Table 2 about here

ACTIVE DUTY ENLISTED PERSONNEL PROGRAM

The first example of longitudinal research using active duty enlisted

Table 2

Incidence Rates for Major Disease Categories by Sex^a

<u>Diagnostic Category</u>	<u>Men</u>	<u>Women</u>
Infectious and Parasitic	770	2,673
Neoplasms	155	738
Endocrine, Nutrition, and Metabolic	98	208
Blood, Blood-forming Organs	31	117
Mental Disorders	1,539	2,754
Nervous System, Sense Organs	311	416
Circulatory System	372	444
Respiratory System	1,499	3,426
Digestive System	1,034	1,702
Genitourinary System	633	2,288
Pregnancy-related Condition	--	4,433
Skin and Subcutaneous Tissue	754	867
Musculoskeletal System	869	1,337
Congenital Anomalies	135	292
Symptoms and Ill-defined Conditions	489	1,747
Accidents, Poisonings, Violence	2,010	2,904
Supplementary Classifications	<u>321</u>	<u>1,347</u>
Total incidence rate	11,020	27,693
Average population	464,582	13,143

^aIncidence rates are the numbers of hospital admissions per 100,000 enlisted population per year for the period 1973-1975.

personnel is shown in Table 2. This table provides a comparison of overall inpatient morbidity by sex (Hoiberg, 1978). The comparison for men and women shows generally higher rates for women for most of the disease categories -- about 2.5 to 1 overall. The largest differences among categories applicable to both groups were found for neoplasms, mental disorders, and the infectious/parasitic disease. The leading causes for hospitalization of women during this period were pregnancy-related conditions. The admission rate for pregnancy-related conditions rose dramatically from the 1960s to the late 1970s -- from about 1,100 per 100,000 in 1966-1969 to 6,400 in 1976. This non-cohort epidemiologic study has implications for redirecting health care resources during the next decade if the proportion of women in the Navy continues to grow.

Insert Table 3 about here

The next non-cohort analysis, shown in Table 3, involves the incidence of cancer in Navy men (Hoiberg and Ernst, in press). Admissions for malignant neoplasms during the period July 1965 through December 1976 were tabulated by organ site and age group, and rates were calculated using average population strengths for each age group. This table shows that cancer is rare among young men, but the rate accelerates sharply after age 35, roughly doubling for each successive five-year interval.

Another non-cohort analysis involves cancer rates by enlisted occupational specialty (Hoiberg and Ernst, 1979a). Construction personnel had the highest overall incidence of malignancies (72 per 100,000 per year) -- almost double the rate for Electronics, Communications, and Electrician personnel (38 per 100,000) at the other end of the continuum. Construction personnel are much more frequently exposed to toxic chemicals in welding

TABLE 3

Incidence of Malignant Neoplasms for Navy Men by Organ Site and Age^a

Organ Site (ICDA-8)	Age Group						
	17-22	23-25	26-30	31-35	36-40	41-45	> 46
Buccal Cavity and Pharynx	1.3	1.5	2.5	3.5	4.9	14.4	16.2
Digestive Organs and Peritoneum	1.1	1.6	2.8	3.7	11.6	19.5	65.0
Respiratory System	.9	.8	1.0	5.3	16.5	36.6	61.5
Bone, Connective Tissue, Skin	5.8	6.6	8.6	10.5	20.8	33.4	75.2
Genitourinary Organs	4.8	7.5	8.8	8.8	12.9	15.8	65.0
Lymphatic and Hematopoietic Tissue	8.4	8.0	9.4	10.8	12.3	25.5	31.6
Other and Unspecified Sites	4.4	5.4	7.4	9.5	14.5	21.8	38.5
Total Malignancies	26.6	31.3	40.4	54.2	93.5	166.8	353.0

^aIncidence rates are average numbers of new cases (hospital admissions) per 100,000 male population per year for the period July 1965-December 1976 (adapted from A. Hoiberg and J. Ernst, "Cancer among Navy personnel," Military Medicine, in press).

and metal-working tasks, and to dust (including asbestos and fiberglass) than most other Navy occupations, so this group would be expected to have the highest cancer rate. However, such inferences can only be considered tentative until more direct exposure data are available.

The above examples of non-cohort methods of analysis demonstrate that major disease trends can be obtained rather quickly and inexpensively. These trends can be used to generate meaningful hypotheses, and point the way to more refined or detailed analyses.

The next example to be presented is a prospective longitudinal cohort analysis that determines whether or not the presence of hemoglobinopathies diagnosed during Navy recruit training is related to subsequent health and performance among Black sailors. Before describing this analysis, distinguishing features of longitudinal cohort analyses will be explained further. The essential characteristics of the longitudinal cohort analysis are: (a) the cohort group or groups are defined before the occurrence of disease, and (b) the groups are observed over a specific period in order to determine frequencies of disease occurrence. A distinction is further made between prospective and retrospective cohort analyses. In the prospective cohort analysis, the incidence of the subsequent disease is not known prior to defining the cohort. In the retrospective analysis, relevant events (causes and effects) have already occurred before the analysis is initiated (MacMahon & Pugh, 1970). Differences do not exist, however, between retrospective and prospective cohort analyses in terms of methodology, scientific interpretations and practical outcomes, assuming the investigator adopts a fixed design or plan for testing hypotheses before beginning the analysis. Generally, for longitudinal analyses using the

Navy Inpatient Medical Data System, labeling the analysis prospective or retrospective has little significance because the categories and measures of disease and performance to be used are usually standardized or fixed before the analysis begins. However, this distinction is important in defining statistical methods to be used in determining the significance of differences between samples.

In this prospective cohort example, 8,725 Black Navy recruits were screened for hemoglobin variants and glucose-6-phosphate dehydrogenase (G-6-PD) deficiency in 1972. Based on the results of these blood analyses, the recruits were grouped into four categories: Sickle trait (N = 599), G-6-PD deficient (N = 1,003), both trait anomalies (N = 73), and neither trait or normal (N = 7,050).

Insert Table 4 about here

In 1978, the Naval Health Research Center medical and service history files of these recruits were searched for appropriate follow-up data, and the four groups were compared on a number of demographic characteristics, indices of military performance and health (Hoiberg, Ernst and Uddin, 1979). Comparisons of the four groups on demographic and pre-service characteristics -- age, marital status, verbal intelligence (as measured by General Classification Test scores), and education -- indicated that differences among groups were not significant for any of these variables. Table 4 presents data on indicators of military performance and medical disability and death. Again, significant differences were not apparent. Finally, rates of total hospitalization for the four groups were compared and found not to differ. Only for the category "Diseases of the Blood and Blood-forming Organs" (including hemoglobinopathies -- a confounding variable)

Table 4

Comparison of Hemoglobinopathy Groups on Military Performance and Health Indicators

<u>Performance Variables</u>	<u>Sickle Cell Trait (SCT)</u>			<u>G-6-PD Deficient</u>			<u>SCT & G-6-PD Deficient</u>			<u>Normal</u>	
	<u>Mean</u>	<u>S.D.</u>		<u>Mean</u>	<u>S.D.</u>		<u>Mean</u>	<u>S.D.</u>		<u>Mean</u>	<u>S.D.</u>
<u>Promotions</u>	1.78	1.28		1.79	1.25		1.68	1.28		1.74	1.26
<u>Demotions</u>	.30	.59		.30	.55		.38	.62		.30	.56
<u>Unauthorized Absence</u>	.47	1.01		.49	1.09		.38	.76		.49	1.10
<u>Desertions</u>	.10	.39		.10	.41		.04	.20		.12	.46
<u>Highest Pay Grade</u>	2.74	1.28		2.68	1.30		2.64	1.41		2.68	1.33
<u>Effective Status</u>	<u>f</u>	<u>z</u>		<u>f</u>	<u>z</u>		<u>f</u>	<u>z</u>		<u>f</u>	<u>z</u>
On active duty/reenlisted	97	16.2		159	15.8		15	20.5		1,152	16.3
Completed enlistment successfully	245	40.9		400	39.9		30	41.1		2,603	36.9
<u>Noneffective Status</u>											
Not recommended for reenlistment	97	16.2		156	15.6		8	11.0		1,182	16.8
Unsuitability Discharge	59	9.8		104	10.4		9	12.3		753	10.7
Disciplinary separation or in deserter status	76	12.7		143	14.3		10	13.7		999	14.2
<u>Medical Separations</u>	20	3.3		39	3.9		1	1.4		328	4.7
<u>Deaths</u>	5	0.8		2	0.2		0	0		33	0.5
Total	599	99.9		1,003	100.1		73	100.0		7,050	100.1
Hospitalization rate (per 100,000 per annum)	12,211			11,375			11,207			12,615	

was a significant effect found. Men with both traits were represented disproportionately in this diagnostic category.

The conclusion of this longitudinal cohort analysis was that examination of the subsequent military performance and health status of the three trait groups compared with a normal sample of Black sailors failed to differentiate the groups in terms of illness rates or impaired performance. This evidence indicated that these genetic trait anomalies were benign. A similar analysis is planned for Marine Corps personnel. Inasmuch as physical exertion is more severe and frequent for Marines than for Navy personnel, the results could conceivably be different than those presented above.

This example demonstrates clearly that cohort analyses provide the basis for more exact estimates of health risks than non-cohort analyses. Results such as those for the sickle cell analysis can usually be translated directly into recommendations and decisions for establishing or modifying policies related to occupational health and safety if significant effects are found. Other examples of longitudinal cohort analyses of Navy enlisted personnel are those conducted by Hoiberg on Vietnam combat personnel (Hoiberg, 1979a), pregnant women (Hoiberg and Ernst, 1979b) and selected occupational groups (Hoiberg and Pugh, 1978).

SUBMARINER/DIVER PROGRAM

Submariners. A systematic analysis of morbidity and mortality patterns among submarine personnel has been of fairly recent origin. With the introduction of ballistic missile nuclear submarines (SSBNs) in the mid- to

late 1950's, interest developed in possible health effects associated with prolonged exposure to this closed environment (50-75 days for each patrol/two or three patrols a year). Nuclear submariners are exposed to a number of unusual conditions, including high carbon dioxide levels (an average level above 1% through the mid-1960's, to a current average of about 0.5%), absence of sunlight, lack of fresh fruits and vegetables, and exposure to high levels of some trace metals. These conditions are present 24 hours a day throughout the patrol period. In addition, chronic exposure to low levels of ionizing radiation has emphasized the importance of longitudinal analyses of health.

Initial analyses of health patterns among active duty submarine personnel during the 1960's demonstrated that submariners were as healthy as, or healthier than, other Navy groups (Austin, 1964; Wilken, 1969). These morbidity rates were determined from the medical section of patrol reports written during a seven-year period (1960-1967). (These reports do not document illnesses or injuries during off-patrol periods, which account for about two-thirds of the yearly cycle.) While morbidity varied substantially across major diagnostic categories, the rate within each category was low. (Comparison groups were not used.) A later analysis of Navy inpatient medical records for the years 1966-1969 (Hester, 1971) showed that submariners had lower morbidity rates for most major diagnostic categories than other Naval personnel (including Marine Corps). Submariners were similar to the comparison sample in rates of tuberculosis, malignant and benign neoplasms, metabolic disorders (including obesity), and diseases of the peripheral nervous system. These findings were essentially replicated in a later analysis (Tansey, Wilson and Schaeffer,

1979) which showed that submariners had lower rates of respiratory, traumatic, gastrointestinal, dermal, infectious and miscellaneous illnesses, and higher rates of genitourinary, systemic (including mononucleosis), cranial, and neuropsychiatric illnesses compared to personnel stationed onboard surface vessels (e.g., destroyers). These data were also collected from sick call records maintained while on patrol. While differences in reporting procedures, periods of reporting (1968-1973 for submariners, 1973 only for surface personnel), and age differences between the samples (surface personnel were several years younger than the submariners) could have mitigated these differences, the overall effects are nonetheless consistent with previous results.

The major problem with the above analyses is that the effects have been derived from acute situations among young, active duty personnel. None of these analyses have involved samples in which long-term, latent health effects could be manifest. To correct this deficiency, a prospective survey of submariner health was established in 1969. The survey involved collecting multiphasic physical and psychological examination data on over 1000 active duty submariners from the Groton, Connecticut area. While the protocol and techniques used to collect these data have been described thoroughly (Sawyer and Baker, 1972; Tansey, 1974), the rationale for the survey was ambiguous. The only possible health consequences of interest that were described were those involving cardiovascular disease (Sawyer and Baker, 1972). Indeed, most of the physical examinations were centered around these effects, with most of the remaining tests used to document sensorimotor status. Results from the initial data collection period

indicated that submariners have distant acuity that is below normal, with more myopia, esophoria and less accommodative power than other men of comparable age (Kinney, Luria, McKay and Ryan, 1979). Cholesterol levels were found to be related positively, and glucose tolerance negatively, to length of submarine service. These effects were independent of age (Tappan, Jacey, Heyder and Harvey, 1979). These latter findings, however, may be confounded by the possibility that personnel with a propensity for high cholesterol levels and poor glucose tolerance remain in submarine service for longer periods than those who have lower cholesterol levels and better glucose tolerance.

After the initial set of examinations described above had been administered to the submariners (mostly between 1972 and 1975), problems with this design became apparent. Location and return of the participants, now distributed between Rota, Spain and Guam, was going to be difficult and costly. Little attention had been paid to the characteristics of the sample, resulting in questions about the degree to which the participants were representative of the total submariner population. Over half of the sample had been enlisted personnel who were in the first four-year tour of active duty. With less than fifteen percent of these personnel likely to re-enlist for a second tour, a major attrition problem existed among the participants. With the sample skewed toward younger personnel, significant health effects would take years to develop and be detected. A comparison cohort was also not available. Another serious problem involved the examinations. If the assumption is made that the survey was redundant with several other civilian and military research programs designed to

document variables related to cardiovascular disease (including the Thousand Aviator Program described below), then the survey could be expected to add little to knowledge of submariner health using these traditional examinations. Rare diseases or conditions such as neoplasms (associated with ionizing radiation), subtle metabolic effects (related to chronic carbon dioxide exposure), or trace metal accumulation, would not be detected reliably using this set of examinations. Additionally, the sample size was too small to determine reliably the true incidence of some of these rarer conditions. Faced with these insurmountable problems and deficiencies, the program was re-directed in 1976 to a computer-based system similar to that described above for the Active Duty Enlisted Program.

In order to obtain a sample of personnel who have had long-term exposure to nuclear submarine environments, and among whom latent health effects, if any, have had a sufficient period in which to develop, only data for retired and Fleet Reserve personnel were included for analysis. (The Fleet Reserve consists of enlisted personnel who are placed in a retainer status after 20 years of active service, and remain in this status until 30 years of service have been completed, after which they are fully retired.) Major identifying information (name, address, Social Security Number, age, submarine qualification and rating/pay grade) will be obtained from the Naval Reserve Personnel Center. Early estimates are that this file will contain approximately 40,000 former submarine personnel. In addition, records of several thousand submariner deaths (Causalty Reports) will be available from the Naval Manpower and Personnel Command. These records (retired personnel and deaths) will be collated with hospitalization data,

including Navy inpatient medical data (described above), as well as inpatient data from Army, Air Force and Veterans Administration hospitals (which retired Navy personnel may use for convenience). Inasmuch as some retired personnel may not have access to military hospital facilities, they may obtain private inpatient care through the Civilian Health and Medical Plan for the Uniformed Services (CHAMPUS). These admissions, too, will be included as part of the project. In addition, Navy Medical Board and Physical Evaluation Board reports will be used for information about personnel with disability retirements.

Length of nuclear submarine service and records of the cumulative low-level radiation dose over an entire submarine career will be obtained from magnetic tape files of dosimetry records (documented on a form called NAVMED 6470/3, and maintained at the Navy Bureau of Medicine and Surgery). Possible relationships between disease-specific morbidity/mortality rates and selected occupational specialties (e.g., those who have access to the nuclear reactor) will be explored.

Disease-specific mortality rates will be developed initially from Casualty Reports and Naval Reserve Personnel Center master records for inactive personnel. Preliminary exploration indicates that diagnostic information in the Casualty Reports is of generally high quality. These records are, however, subject to the common limitations of death certificates. For deaths among retired and Fleet Reserve personnel associated with admissions to Army/Air Force, Veterans Administration or CHAMPUS hospitals, information relevant to cause of death beyond that appearing in the Casualty Reports will be available.

The data can be classified into three types: outcome variables, exposure variables, and extraneous or confounding variables. Outcome variables can relate to either morbidity or mortality. For each individual, mortality variables would be the presence or absence of death from a specific cause, while morbidity variables would be the presence or absence of a specific disease or condition, or perhaps a continuous response such as level of blood pressure.

Inasmuch as this project is a recent development, data are not yet available. Reports of the initial analyses are expected in early 1982.

Divers. While a formal program to analyze health patterns among members of the Navy diving community does not exist presently, the data resources for such a program are readily available. While the Active Duty Enlisted Personnel and Submariner programs described above are severely constrained by the availability of detailed exposure data (either because exposure has not been documented routinely or because such data are classified - especially in the case of submariners), the occupational activities of Navy divers are well documented. Highly detailed and reliable descriptions of diving exposures have been maintained since 1970 by the Naval Safety Center, Norfolk, Virginia. In that year, both routine and experimental dives were documented on standard record sheets using simple alphanumeric entries. If the dive resulted in an accident (i.e., decompression sickness, air embolism, drowning, and so forth), this information is also entered onto the same form using a standard format. This record, called the "Combined Diving Log - Accident/Injury Report" (OPNAV Form 9940/1), replaces two previous forms containing extensive narrative descriptions and non-standard

data entries. The present diving record is designed to be easily key-punched and entered into computer files.

Insert Table 5 about here

The diving exposure data recorded on this form are listed in Table 5. Information is provided about diver characteristics, the diving environment, protective clothing and life support equipment, the dive schedule and profile, and accident parameters (if an accident occurred in association with the dive). Subsets of information within these categories are codified and entered onto the diving record sheet and mailed quarterly to the Naval Safety Center. (Detailed descriptions of these subsets may be obtained from the overlays--OPNAV Form 9940/1A--used in conjunction with OPNAV 9940/1 or from the U. S. Navy Diving Manual, volume 1, "Air Diving", both of which may be obtained from the Supervisor of Diving, Naval Sea Systems Command, Washington, D. C. 20362.)

While little use has been made of the above data for longitudinal analyses, such use is planned in the near future. These diving history data can be collated readily with the Navy Inpatient Medical Data System (for both active duty and retired personnel as described above) so that long-term health effects can be linked to various patterns of diving exposure. To date, these diving history data have been used to describe diving activity generally, and for determining diving exposure factors that may be related to the incidence of decompression sickness (Biersner, 1975), as well as to a degenerative bone disorder (aseptic bone necrosis) that appears to afflict divers who may be especially susceptible to decompression sickness (Hunter, Biersner, Sphar and Harvey, 1978). The data have been used additionally to differentiate between young and old divers (Biersner,

Table 5

Data Available from the Combined Diving Log-Accident Injury Report

Diver Information

Name
 Social Security Number
 Unit identification code
 Unit name
 Age
 Height
 Weight
 Build
 Sex
 Race
 Marital status
 Branch of service
 Diver qualification
 Number of dives in previous
 24 hours

Environmental Data

Date and local time
 Latitude
 Longitude
 Water depth
 Wave height
 Current (force in knots)
 Air temperature
 Surface water temperature
 Bottom water temperature
 Visibility (feet)
 Composition of bottom (mud,
 sand, rock, coral, etc.)

Equipment/Breathing Mixture

Type of diving suit (dry, wet,
 deep sea, etc.)
 Type of breathing apparatus (SCUBA,
 deep sea mixed gas, etc.)
 Breathing mixture (percent of O₂,
 N₂, etc.)
 Supply source of breathing mixture
 (compressor, air banks, etc.)

Dive Characteristics

Purpose of dive (work, training, etc.)
 Depth
 Total time at maximum depth
 Type of work (none, mild, moderate
 and heavy)
 Type of tools
 Equipment rating (satisfactory, below
 par, and unsatisfactory)
 Diver rating (Satisfactory, below par,
 and unsatisfactory)
 Type of decompression schedule
 Interval since last dive (if less than
 24 hours)
 Location of decompression (water, chamber,
 etc.)

Accident Data (if applicable)

Diagnosis (drowning, air embolism, etc.)
 Time of occurrence (first sign or symptom)
 Cause (if determined)
 Number of dives in last 10 days
 Recurrence (from previous treatment)
 Most significant initial sign or symptom
 (code number)
 Location of this sign or symptom (code
 number)
 Primary organ system involved (code number)
 (Additional entries similar to above are
 available for four more signs and symptoms
 if needed)
 Time treatment commenced
 Time treatment completed
 Recompression table used in treatment
 (if applicable)
 Breathing gas used
 Type of treatment personnel (physician,
 corpsman, etc.)
 Treatment outcome (complete/substantial
 relief, recurrence, or fatal)
 Days lost from duty
 Autopsy conducted (yes or no)

Dembert and Browning, 1978), normal and asocial divers (Biersner, Dembert and Browning, 1979), and divers who make exceptionally hazardous dives and those who make routine dives (Biersner, Dembert and Browning, in press). These analyses demonstrate that these diving history data hold immense promise for improving knowledge of an extremely complex and dangerous occupation.

THOUSAND AVIATOR PROGRAM

The oldest longitudinal health program still ongoing in the United States is the Thousand Aviator Program. In addition to being the senior research program of this type, the Thousand Aviator Program had the distinction (and advantage) of involving participants who were comparatively young, and who were a more homogeneous group medically, psychologically and socially than is true of most other longitudinal programs. Measurement variability is therefore restricted, resulting in improved reliability and validity of the findings. In addition, most of the participants were career officers, thereby ensuring adequate long-term follow-up.

While in the later years of this program emphasis has been on the medical consequences (especially the cardiovascular effects) of aging, the program was initiated originally to select aviator candidates for flight training because such training was lengthy and expensive, and reliable and easily administered screening and selection methods had long been sought. After initial interest during the first World War, little additional medical screening research was conducted until 1939. In that year, the Committee on Selection and Training of Civilian Aircraft Pilots of the National Research Council received funds from the Civil Aeronautics Authority (now

Federal Aviation Agency) for use in planning and supervising aviation medical research. In the summer of 1940, the Council expanded this charter to include military aviation and, in cooperation with the U. S. Navy, began the program that became known as "The Pensacola Study of Naval Aviators," or the "Thousand Aviator Program."

The 1940 program explored the use of psychological and physiological testing in prediction of flight training success. Criteria included (a) passing or failing the flight course, and (b) negative actions by the Commandant's Board (a panel of officers that reviewed the course grades and performance of marginal candidates). The program was designed to determine as quickly as possible (in anticipation of combat needs) the measures deemed most promising for selection of candidates for flight training. The original plans called for participant follow-up only through the flight training course.

The first group to be examined consisted of incoming cadets and officers in each flight class at Pensacola during the period from July 16 through September 20, 1940 (classes 147 through 151; N = 479). Twelve cadets and officers were tested each day during the ground school period prior to flight training. The officers in this sample were Naval Academy graduates who were commissioned as Ensigns, while the cadets were college graduates who were waiting to be commissioned.

Because of the small number of failures in the above group, a decision was made subsequently to extend these examinations. From October 1 to December 15, 1940, a representative sampling comprising about one-fifth of each incoming class (classes 152 through 159) was tested. During this period,

only five participants could be tested each day because of reductions in the research staff. From January 1 to May 15, 1941, cadets from classes 160 through 165 were examined who appeared before the Commandant's Advisory Board (for a screening interview). This second sample (classes 152-165; N = 750) consisted of men who had either a high school diploma or two years of college, but who would be commissioned on completion of flight training. The members of both samples were between 20 and 30 years of age and had passed some form of medical screening prior to admission to the flight program. In addition, they had completed a preliminary ten-hour flight training course, including solo flight, before being sent to Pensacola for more extensive training. Personnel who failed the medical screening and preliminary flight training were not examined for the Thousand Aviator Program. A group of 83 instructors at the Naval Air Station (Pensacola) were also examined so as to obtain normative data for pilots known to be successful. The average age of this group was 27 years, and they had accumulated an average of 1,500 flight hours. The physical, biochemical and psychological measures administered to these groups during this initial evaluation, as well as measures used during subsequent evaluations (in 1951, 1957, 1963 and 1969) are presented in Table 6.

Insert Table 6 about here

Following the end of World War II, the usefulness of this large, homogenous group of healthy young men for a unique, prospective analysis of the aging process became apparent. Re-evaluation of the living members of the group who had undergone evaluation in 1940 became the major goal of the program. A follow-up analysis of this group after an interval of ten or more years could be a source of much useful informa-

Table 6

Medical Evaluation Tests Used for the Thousand Aviator Program^a

Tests	Evaluation Period				
	1940	1951	1957	1963	1969
<u>Interview: Personal and medical histories</u> ^b	*	*	*	*	*
<u>Physical examination</u>	c	*	*	*	*
<u>Cardiovascular</u>					
routine electrocardiogram	*	*	*	*	*
startle electrocardiogram	*				
computer processed electrocardiogram				*	*
exercise electrocardiogram			*	*	*
ballistocardiogram			d	*	*
vectorcardiogram				*	*
plethysmogram				*	
cold pressor test	*		d		*
other	*			*	
<u>Laboratory determinations</u>			*	*	*
<u>Pulmonary and metabolic</u>					
spirometry	*			*	*
basal metabolic rate	*				
other	*			*	
<u>Anthropometry</u>					
somatotype	*			*	*
measurements (in addition to height & weight)			e	*	*
<u>Teleoroentgenograms</u>		*	*	*	*
<u>Psychologic-Psychomotor</u>					
Guilford-Zimmerman Temperament Survey				*	*
ataxia test	*			*	
tilt chair	*			*	
other	*			*	
<u>Vision</u>	*			*	*
<u>Neurophysiologic</u>					
electroencephalogram	*			*	
skin resistance	*				
<u>Audiometry</u>				*	*

^aCompletion of the tests is noted by an asterisk; if a procedure was not performed during an evaluation, the appropriate column is blank.

^bPersonal and medical histories include alcohol, smoking, and exercise histories.

^cOnly blood pressures were recorded because each member had qualified medically before inclusion in the study.

^dExaminations performed on less than 25 per cent of the study group.

^eArm circumference only.

tion for development of future diagnostic and treatment methods. The first follow-up analysis (in 1951) was therefore designed to estimate the current physical status of the group with particular emphasis on the cardiovascular system, morbidity and mortality rates, and whether or not aviation experience was related to these effects. Findings were to be compared with the data collected in 1940-41.²

Identification of important physiologic precursors of disease, especially cardiovascular disease, requires longitudinal analysis. Although several epidemiologic programs with these goals have been initiated since 1940, these programs involve primarily middle-age samples. Hence, an important phase in the pathogenesis of the disease has necessarily been neglected -- namely, subtle physiologic differences during the young adult years. These early physiologic differences, and associated environmental factors, can not be determined in programs confined to older age groups. In addition, only from long-term programs involving young, healthy participants can normal standards be developed that permit diagnosis of asymptomatic, sub-clinical disease. The results of serial examinations provided a unique opportunity to determine the relationship of blood pressure and electrocardiograms to aging and to the onset of cardiovascular disease (Packard, Graettinger and Graybiel, 1954; Harlan, Osborne and Graybiel, 1962; Harlan, Osborne and Graybiel, 1964). These research findings, as well as program redirection, were the major outcomes associated with the 1951 follow-up analysis.

Following an interim evaluation in 1957, the next major evaluation occurred in 1963. This evaluation was designed to be the most comprehensive

² Of the 1312 participants examined in 1940-41, positive identification and/or location was made of 1056 participants in 1951. The vast majority of those not positively located or identified had failed aviator training and follow-up information was unavailable.

survey of the participants to date. These men had now reached an age at which detection of latent disease was highly probable. With the interest and support generated by previous evaluations, thorough examinations could now be conducted at the Naval School of Aviation Medicine, in contrast to the previous follow-up examinations that were conducted by a team of Navy physicians who traveled about the country in a mobile laboratory unit. This capability enabled the research staff to perform a more detailed physiological appraisal not possible in the previous two evaluations. The participants were provided commercial air transportation to Pensacola for two days of extensive testing, during which every important physiological measurement included in the earlier examinations was repeated. In addition, tests that were not possible to conduct in the field, or that were not previously available, were used. Much of this additional support and interest came from the Heart Disease Control Program of the U. S. Public Health Service.

Preliminary questionnaires were sent to 815 participants during the latter part of 1962 requesting information concerning recent health, occupation, flying and military status. Actual testing began in January, 1963 and continued until early 1965. Tests and procedures were standardized as much as possible. Many of the forms were designed for computer analysis. The major findings of this evaluation, used in conjunction with previous data, were a determination of the (a) serum lipid status of the group and the usefulness of this measure as an indicator of cardiovascular health (Harlan, Osborne and Graybiel, 1963), (b) independent contributions made by various physiologic measures in prediction of cardiovascular health

(Harlan, Osborne and Graybiel, 1963), (b) independent contributions made by various physiologic measures in prediction of cardiovascular health (Oberman, Doll and Graybiel, 1964; Harlan, Graybiel and Osborne, 1965), (c) correlations of ballistocardiograms and systolic blood pressure with precursors of cardiovascular disease (Jackson, Oberman, Mitchell and Graybiel, 1967; Oberman, Lane, Harlan, Graybiel and Mitchell, 1967), and (d) distribution of vestibular performance across various age groups (Fregly, Oberman, Graybiel and Mitchell, 1968).

The most recent evaluation occurred in 1969-1971. In this 29th year of the program, most of the participants were entering the sixth decade of life. The 1969 program was conducted in a fashion similar to the 1963-65 program in order to maintain uniformity and standardization of procedures. Beginning in 1968, participants were contacted, sent preliminary questionnaires, and subsequently tested for two days at the Naval Aerospace Medical Institute in Pensacola, Florida. The findings of this evaluation were used to describe pulmonary function and blood pressure patterns over the course of 30 years (Mitchell, 1972; MacIntyre, Mitchell, Oberman and Graybiel, 1977). As of 1977, only 95 of the participants had died of non-military illnesses and injuries, a rate less than half that expected of a random sample of white American males born during the same period (MacIntyre, Mitchell, Oberman, Harlan, Graybiel and Johnson, 1978).³ The death rate was especially low for non-aviation accidents, about 10% of the expected number. The low death rate among the participants was attributed to a higher than normal socioeconomic background, better than average intelligence, superb health maintenance and physical fitness, high intelligence, and a genetic predisposition to longevity.

³ Of the 1056 original participants positively identified in 1951, 682 were known to be alive in 1977. An additional 23 were located through VA or IRS sources. The status of 28 could not be determined. A total of 228 had died of military-related aviation accidents during World War II and the Korean conflict.

Future research in this program will be directed toward redefining the medical screening standards for older (45+ years), active duty aviators in order to determine if continued flight duty is possible. This extension of duty is necessitated by a severe shortage and poor retention of younger aviators. These new standards, however, must be based not only on future health risks, but on the ability of these personnel to perform a number of aviation tasks satisfactorily. The Federal Aviation Administration may use these standards for screening commercial pilots for retirement as well. In future years, physical and psychological examination of the participants in the Thousand Aviator Program will be curtailed, but morbidity and mortality data will continue to be collected routinely through questionnaires.

Brief mention should also be made of another longitudinal health program involving mostly aviators--that directed toward the repatriated prisoners of the Vietnam War (RPOWs). The RPOWs, who were released from incarceration in 1973, consisted of 141 Navy and 37 Marine Corps men, 140 of whom were aviators. The aviator subgroup is being examined annually using the physical and psychological measures listed in Table 7. In addition, a comparison group of aviators matched for age, rank, and flight experience is being tested using the same measures. To date, the two groups have been found not to differ significantly on a number of personality measures (as determined from responses to the Jackson Personality Research Form A). The comparison group was, however, found to suffer a more significant high frequency hearing loss than the RPOW group. A number of other comparison data will be available in the near future.

Insert Table 7 about here

Table 7

Medical Evaluation Tests used for the RPOW Program

<u>Tests</u>	1974	1975	<u>Evaluation Period</u>			
			1976	1977	1978	1979
<u>History (including demographics)</u>	*	*	*	*	*	*
<u>Physical examination</u>	*	*	*	*	*	*
anthropometries	*	*	*	*	*	*
<u>Laboratory</u>						
hematology	*	*	*	*	*	*
total eosinophile counts	*					
urinalysis	*	*	*	*	*	*
SIAC 18 or 24	*	*	*	*	*	*
glucose tolerance test	*	*	*	*	*	a
stool studies						
O&P, occult blood	*	*	*	*	*	*
total lipids (electrophoresis)						
phenotype				*		
HDL					*	
total proteins (electrophoresis)	*	*	*	*	*	*
immunoglobulins	*					
thyroid profile	*					
<u>X-rays</u>						
cardiac series	*					
PA, lateral (chest)		*	*	*	*	*
flat plate abdomen	*					
hands	*	*				
<u>Electrocardiograms</u>						
routine fasting	*	*	*	*	*	*
stress (Bruce protocol)	*	*	*	*	*	*
<u>Vectrocardiograms</u>	*	*	*	*	*	*
<u>Ballistocardiograms</u>	*	*	*	*		
<u>Pulmonary function studies</u>	*	*	*	*	*	*
<u>Audiograms</u>	*	*	*	*	*	*
<u>Vestibular and special visual studies</u>	*					
<u>Special consultation^a</u>	*	*	*	*	*	*
<u>Psychiatry interview</u>	*	*	*	*	*	*
<u>Psychological testing</u>	*	*	*	*	*	*

^aAs indicated.

FUTURE DIRECTIONS

Longitudinal research in the U. S. Navy will most likely become dominated by computer-based technology during the next five to ten years. This direction is necessitated by scarce resources, including both skilled personnel and fiscal support. Additionally, such direction makes optimum use of unique Navy data files and the availability of long-term follow-up medical and personnel information. The Navy is most likely to be interested in determining the incidence and prevalence of rare diseases contracted as a result of unique occupational exposures, especially those diseases associated with ionizing, microwave and extremely low frequency radiation, heavy metal contamination, long-term exposures to carbon monoxide and dioxide, as well as atmospheric hydrocarbons and fluorides, and disease states related to chronic hyperbaric exposures (particularly the medical effects of decompression sickness). These rare conditions necessitate the use of computer-based epidemiology instead of serial medical examinations. The causal factors involved in these diseases can be determined more precisely through environmental monitoring and medical examination after the computer-based system has identified significant diseases and the major characteristics of those who are at risk. In this manner, computer-based longitudinal research will serve as a planning and screening technique, permitting improved allocation and direction of resources in determining disease causality.

Cost-effective use of computer-based epidemiology requires that corrections and improvements be made to the present system. New epidemiologic methods are needed to provide the basis for more comprehensive and dynamic

models of morbidity. Fundamental difficulties with the most commonly used epidemiologic method, the case-control method, have been noted above. Another limitation of classical epidemiologic methods is the tendency to limit analyses to the effects of single variables. Methods are needed that estimate the effects of a number of causal variables or risk factors simultaneously. Also, methods should document trends over long periods, including variations in both risk factors and illness rates.

Insert Table 8 about here

The limitations of classical epidemiology become most apparent in trying to account for the many possible risk factors that are now presumed to be related to health and longevity. Table 8 provides only a partial list of these risk factors. Many more factors could probably be added from the epidemiology literature. Unfortunately, methods and techniques are not available to represent these complex conditions in any valid, integrated way.

Specific examples of dynamic risk factors in naval settings include transfers from one occupation to another or from one duty station to another; implementation of effective occupational health and safety programs; variations in smoking or drinking habits; and participation in weight reduction or physical conditioning programs. Aging, of course, represents a ubiquitous and important risk factor. For example, on one current longitudinal health analysis, illness incidence was found to be markedly higher in the third decade of naval service than in the second decade among career enlisted personnel (Hoiberg, 1979b). Higher risk with age is more pronounced in occupational specialties such as Construction, Engineering, and Service ratings for disease categories such as Circulatory Diseases, Neoplasms, and Endocrine, Nutritional, and Metabolic Disorders, than in other occupations

Table 8

Possible Risk Factors in Morbidity/Mortality

<u>Host Characteristics</u>	
<u>Genetic Predispositions</u>	<u>Health History</u>
Body type	Congenital deformities
Blood type	Natural immunities
Parents' longevity	Immunizations by inoculation
	General susceptibility
<u>Demographic Variables</u>	Diet
Sex	Exercise
Age	Smoking
Race or ethnic group	
Socioeconomic status	<u>Personality</u>
Intelligence/Education	Impulsiveness
Occupation/Specialized training	"Type A"
Marital status	Defenses/coping skills
<u>Agents</u>	
<u>Physical</u>	<u>Toxic Chemicals</u>
Noise	Solvents
Heat/Cold	Fuels
Radiation	Lubricants
Foreign bodies	Pesticides
Vibration	Fumes/gases
Violence (weapons, explosives)	Therapeutic drugs
Machinery	Drug/Alcohol addiction
Motor vehicles	
Water (drowning)	<u>Social</u>
<u>Biological</u>	Crowding/Geographic mobility
Infectious/Parasitic microorganisms	Crime
Viruses	Sanitation
	Emotional Stress/Overwork/Fatigue
<u>Environmental Variables</u>	
<u>Physical</u>	<u>Medical Care Systems</u>
Urban-rural	Availability
Climate/Weather/Altitude	Quality
Air pollution/Allergens (pollen, etc.)	Specialized services
<u>Social</u>	Education
Economic conditions (unemployment, etc.)	Prevention
Family structure	
Customs/cultural beliefs	
Group memberships/Affiliations	

or diseases.

Important tasks ahead include better delineation of causal factors (including dynamic factors) in disease and injury incidence, and the construction of more comprehensive and valid morbidity models to represent the health of groups or populations in terms of dynamic risk factors and subsequent illness.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Longitudinal health research has important uses in military medicine including estimation of the distribution and relative risks of disease and injury in military populations, discovery of the determinants or causes so that prevention and control can be implemented, and definition of health care needs so that scarce medical resources can be optimally allocated. Three Navy longitudinal research programs are described in some detail and examples of methods and study results are presented. The Thousand Aviator Program, instituted		

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in 1940, was a prospective study designed to determine the etiology of cardiovascular disease among naval aviators. The Submariner/Diver Program was a retrospective study which involved analysis of health effects associated with environmental conditions experienced aboard submarines. The general epidemiological studies under the Active Duty Enlisted Personnel Program are designed to be either prospective or retrospective and to utilize the total archival inpatient medical data files of the U.S. Navy. Some of the limitations of classic epidemiologic methods and the need for more comprehensive morbidity models which incorporate dynamic risk factors are discussed.

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